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AZUSA PLANT

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Subject: Informal Monthly Report on the Investigation of Stress-Corrosion Cracking of High Strength Steels for the Month of November 1963, Report No. L0414-02-4

To: U.S. Army Ordnance Corps
Frankford Arsenal
Philadelphia, Pennsylvania

Reference: Contract DA-04-495-ORD-3069, Modification No. 4

This is the twenty-eighth in a series of monthly informal progress reports submitted in partial fulfillment of the contract. It constitutes the fourth monthly report on the second 1-year continuation of the original 2-year program. It was written by R. B. Setterlund, who was supervised by A. Rubin.

I: OBJECTIVES

A. To study the stress-corrosion characteristics of 18%-nickel maraging steel with respect to compositional variation.

B. To study the effect of environmental temperature on the rate of stress-corrosion cracking in three alloys: 18%-nickel maraging steel, a low-alloy martensitic steel, and a hot-worked die steel.

C. To study the electropotential changes occurring in 18%-nickel maraging steel during stress-corrosion exposure, and the effect of applied potential.

II. WORK PROGRESS

A. COMPOSITIONAL VARIATION

In order to study the effects of compositional variation, four heats of 18%-nickel maraging steel were obtained from three vendors. The chemical analysis of these materials are shown in the attached Table 1.

Stress-corrosion tests have now been started on three of the four heats. Three replicate tests are being conducted for each test condition, using beam specimens stressed elastically to 75% of the yield strength as well as

plastically deformed U-bend specimens. Testing is currently under way in distilled water (Table 2), 3%-NaCl salt solution in distilled water (Table 3), and 140°F water-saturated air (Table 4). Seacoast atmospheric testing is scheduled to start later this month (December).

The results obtained to date have not shown a direct relationship between material strength and failure time in all environments. Similar results were obtained in the work of the previous year (Aerojet Report No. 2684). Further testing time will be required before positive conclusions may be drawn.

Center-notched specimens are now being prepared for fracture toughness, and electrochemical and stress-corrosion crack-propagation tests.

The fracture toughness values for the four heats of maraging steel as well as the Ladish D6AC steel, for comparison, will be presented in the next quarterly report due 15 January 1964.

B. ENVIRONMENTAL TEMPERATURE EFFECTS

In order to determine the effect of environmental temperature on stress corrosion failure time, the distilled water tests are being repeated at 120 and 160°F. Tests at other temperatures will be added as time permits. Table 5 lists the results obtained in tests at 120°F.

Based on the limited U-bend tests to date we find that environmental temperature has a definite effect on stress corrosion failure. The stress-corrosion susceptibility of the 20%-nickel grade of maraging steel appears to be greatly lessened by an increase in environmental temperature while the 18%-nickel grades have a shorter time-to-failure at temperatures above ambient.

C. ELECTROCHEMICAL CHANGES

Center-notched specimens are being machined for this series of tests. Preliminary experiments utilizing material from the previous work have shown a linear relationship between applied stress and the electrochemical potential at the tip of the stress-corrosion crack. Future work will involve the measurement of electrochemical changes occurring in 18%-nickel maraging steel during stress corrosion

exposure, and the effect of applied potential. The instrumentation for this task has been undergoing development. Both the test procedure and some early results will be reported in next month's quarterly report.

D. COATINGS EVALUATION

Results to date on the coatings evaluation study are shown in Table 6. Three coating systems that show some degree of effectiveness in preventing stress-corrosion cracking of H-11 steel are being evaluated on a single heat of 18% nickel maraging steel. Each of these three coatings offers a different means of protection. The polyurethane coating forms a thin, dense barrier between the environment and the metal. The inorganic zinc coating serves to provide cathodic protection to the metal while the inhibited epoxy coating protects the metal by means of chromate compounds within the coating. As shown in Table 6, the zinc-bearing coating shows no protective ability on maraging steel. The effectiveness of the other two coatings cannot be established until longer exposure times are completed.

AEROJET-GENERAL CORPORATION

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TABLE 1

MILL-CERTIFIED CHEMICAL ANALYSIS OF PROGRAM MATERIALS

Trade Name	Supplier	Heat No.	Composition, %														
			C	Mn	P	S	Si	Ni	Co	Mo	Al	Cr	Zr	Ti	Ca	B	V
*(a) Maraging Steel from Previous Program																	
RSM 250	Republic Steel	5960502	0.02	0.08	0.007	0.006	0.15	18.48	7.00	4.84	0.21	0.10	0.035	0.50	--	0.0036	
--**	Allegheny-Ludlum	448	0.029	0.002	0.004	0.008	0.009	18.51	8.48	4.92	0.089	--	--	0.52	--	--	
Almar 18	Allegheny-Ludlum	W-24178	0.012	0.01	0.003	0.005	0.01	18.69	8.90	4.92	0.029	--	0.003	0.62	0.005	0.002	
--**	Allegheny-Ludlum	476	0.02	0.08	0.006	0.005	0.014	18.60	9.05	4.90	0.078	--	--	1.00	--	--	
Almar 20	Allegheny-Ludlum	W-24254	0.009	0.09	0.002	0.005	0.06	20.41	--	--	0.29	--	0.002	1.40	0.004	0.003	
(b) Maraging Steel for Present Program																	
RSM 200	Republic Steel	5960525	0.029	0.06	0.005	0.006	0.05	17.79	8.50	3.48	0.13	--	--	0.23	--	--	
Vascomax 250	Vanadium Alloys	07868	0.02	0.09	0.004	0.005	0.10	17.75	7.60	4.60	0.08	--	0.017	0.52	0.05	0.004	
Marvac 18	Latrobe Steel	C56858	0.03	0.03	0.004	0.008	0.05	18.54	8.00	4.75	0.11	--	0.03	0.49	--	0.004	
Vascomax 300	Vanadium Alloys	07268	0.03	0.05	0.004	0.006	0.04	18.54	9.06	4.88	0.09	--	0.088	0.55	0.02	0.003	
(c) Conventional High-Strength Steels																	
Vascojet 1000	Vanadium Alloys	07914	0.38	0.21	0.010	0.008	0.92	--	--	1.33	--	4.75	--	--	--	--	0.51
Ladish D6AC	Allegheny-Ludlum	W-23217	0.495	0.62	0.009	0.009	0.20	0.57	--	0.94	--	1.00	--	--	--	--	0.05

*Some material from previous program will be used to obtain supplementary data.

**Experimental 400-lb heats.

TABLE 2

STRESS-CORROSION TEST RESULTS
DISTILLED WATER

Material	Heat No.	Yield Strength ksi	Failure* Ratio	Failure Time, hours	
				Mean	Range
		Bent Beam Tests**			
20%-Ni Maraging Steel	W-24254	291.3	3/3	11	10.2-18
18%-Ni Maraging Steel	3960523	181.5	0/3	-	NF 985
	07868	248.2	0/3	-	NF 310
	3960502	249.9	3/3	68	50-85
	C56858	267.7	0/0	-	-
	07268	279.1	3/3	500	483-512
18%-Ni Maraging Steel	W-24178	283.0	3/3	34.5	20.5-27.5
		U-Bend Tests***			
20%-Ni Maraging Steel	W-24254	291.3	2/2	3.5	1.4-5.5
18%-Ni Maraging Steel	3960523	181.5	0/3	-	NF 1080
	07868	248.2	2/3	630	480-NF 790
	3960502	249.9	0/2	-	NF 170
	C56858	267.7	0/0	-	-
18%-Ni Maraging Steel	07268	279.1	1/3	1200	407-NF 1600
D6AC Steel	W-23217	203.1	0/2	-	NF 168
		204.6	0/2	-	NF 168
		214.5	0/2	-	NF 168
D6AC Steel	W-23217	237.4	2/2	4.0	1.2-6.8

*Ratio of samples failed to samples tested.

**Samples stressed to 75% of yield strength.

***Samples stressed beyond yield strength.

TABLE 3

STRESS-CORROSION TEST RESULTS
3%-NaCl SOLUTION

Material	Heat No.	Yield Strength ksi	Failure* Ratio	Failure Time, hours Mean	Failure Time, hours Range
		Bent-Beam Tests**			
20%-Ni Maraging Steel	W-24254	291.3	3/3	7.3	6-8.5
18%-Ni Maraging Steel	3960523	181.5	0/3	-	NF 1000
	07868	248.2	0/3	-	NF 310
	3960502	249.9	3/3	430	140-700
	C56858	267.7	0.0	-	-
	07268	279.1	2/3	545	119-NF 1400
18%-Ni Maraging Steel	W-24178	283.0	3/3	52	19-100
		U-Bend Tests***			
20%-Ni Maraging Steel	W-24254	291.3	2/2	2.4	1.9-2.9
18%-Ni Maraging Steel	3960523	181.5	0/3	-	NF 1080
	07868	248.2	1/3	604	312-NF 750
	3960502	249.9	0/0	-	-
	C56858	267.7	0/0	-	-
18%-Ni Maraging Steel	07268	279.1	0/3	-	NF 1600
D6AC Steel	W-23217	203.1	0/2	-	NF 168
		204.6	0/2	-	NF 168
		214.5	0/2	-	NF 168
D6AC Steel	W-2317	237.4	2/2	1.0	0.8-1.2

*Ratio of samples failed to samples tested.

**Samples stressed to 75% of yield strength.

***Samples stressed beyond yield strength.

TABLE 4

STRESS-CORROSION TEST RESULTS
140°F WATER-SATURATED AIR

Material	Heat No.	Yield Strength ksi	Failure* Ratio	Failure Time, hours	
				Mean	Range
		Bent Beam Tests**			
20%-Ni Maraging Steel	W-24254	291.3	3/3	100	22-174
18%-Ni Maraging Steel	3960523	181.5	0/3	-	NF 1000
	07868	248.2	0/3	-	NF 310
	3960502	249.9	3/3	370	170-475
	C56858	267.7	0/0	-	-
	07268	279.1	2/3	750	320-NF 1400
18%-Ni Maraging Steel	W-24178	283.0	3/3	21	20.5-21.5
		U-Bend Tests***			
18%-Ni Maraging Steel	3960523	181.5	4/4	252	120-407
	07868	248.2	3/3	378	282-426
	3960502	249.9	0/0	-	-
	C56858	267.7	0/0	-	-
18%-Ni Maraging Steel	07268	279.1	3/3	527	470-640
D6AC Steel	W-23217	203.1	0/2	-	NF 168
		204.6	0/2	-	NF 168
		214.5	0/2	-	NF 168
D6AC Steel	W-23217	237.4	2/2	1	1

*Ratio of samples failed to samples tested

**Samples stressed to 75% of yield strength.

***Samples stressed beyond yeild strength.

TABLE 5

STRESS-CORROSION TEST RESULTS
120° DISTILLED WATER

Material	Heat No.	Yield Strength ksi	Failure* Ratio	Failure Time, hours Mean	Failure Time, hours Range
		Bent Beam Tests**			
18%-Ni Maraging Steel	396052	181.5	0/3	-	NF 24
	07868	248.2	0/3	-	NF 24
	3960502	249.9	0/3	-	NF 24
	C56858	267.7	0/0	-	-
18%-Ni Maraging Steel	07268	279.1	0/3	-	NF 24
		U-Bend Tests***			
20%-Ni Maraging Steel	W-24254	291.3	2/3	245	180-NF 360
18%-Ni Maraging Steel	3960523	181.5	2/3	313	245-NF 360
	07868	284.2	3/3	196	180-218
	3960502	249.9	2/2	133	121-144
	C56858	267.7	0/0	-	-
18%-Ni Maraging Steel	07268	279.1	1/3	350	331-NF 360
D6AC Steel	W-23217	203.1	0/2	-	NF 360
		204.6	0/2	-	NF 360
		214.5	1/2	348	335-NF 360
D6AC Steel	W-23217	237.4	2/2	2.3	1.6-3

*Ratio of samples failed to samples tested.

**Samples stressed to 75% of yield strength.

***Samples stressed beyond yield strength.

TABLE 6

BENT-BEAM STRESS-CORROSION TESTS,
COATINGS EVALUATION RESULTS TO 12-1-63

Base Material	Coating	Aerated 3%-NaCl Solution			140°F Water-Saturated Air		
		Failure Ratio	Failure Time, hours		Failure Ratio	Failure Time, hours	
			Mean	Range		Mean	Range
H-11 Steel	None	4/4	1.6	0.8-2.5	2/2	64	48-70
↓	Polyurethane X-500	3/3	149	144-168	6/6	3500	2830-5500
↓	Inorganic Zinc 11	2/2	687	674-702	2/2	821	723-819
H-11 Steel	Inhibited Epoxy 454-1-1	0/2	-	NF 3100	3/3	2720	2590-2850
18%-Ni Maraging Steel	None	2/3	545	119-NF1400	2/3	750	320-NF1400
↓	Polyurethane X-500	0/3	-	NF1250	0/3	-	NF1250
↓	Inorganic Zinc 11	3/3	339	72-648	3/3	150	140-170
18%-Ni Maraging Steel	Inhibited Epoxy 454-1-1	0/3	-	NF1250	1/3	1215	1150-NF1250